7.0 DESCRIPTION OF GROUNDWATER REMEDIATION ALTERNATIVES

An FS was conducted to develop and evaluate remedial alternatives for the Offpost OU. The first task performed during the FS was to identify media that require remedial action and correspondingly require development and evaluation of remedial alternatives. Risks calculated in the EA were compared to acceptable risk levels established by EPA in the NCP and other guidance. The Army has closely followed EPA guidance and the National Contingency Plan (NCP) regarding the use of the 10^{-4} risk threshold to assess whether remediation is necessary. Guidance states that if the cumulative cancer risk to an individual is less than 10^{-4}, remedial action may not be warranted unless certain site-specific conditions exist. If remedial action is warranted, then the 10^{-4} to 10^{-6} risk range must be achieved, with an initial preference for the 10^{-6} end. EPA guidance further states that the upper boundary of the risk range is not an absolute at 1×10^{-4}, but rather, the acceptable risk range can extend to 5×10^{-4}. The cumulative offpost cancer risk is a maximum of 3×10^{-4}, which is within the acceptable risk range.

In explaining the use of the point of departure, the EPA, in the preamble to the NCP, states

- The use of 10^{-6} expresses EPA's preference for remedial actions that result in risks at the more protective end of the risk range, but does not reflect a presumption that the final remedial action should attain such a risk level (55 FR 8718).

The operation of the Offpost Groundwater Intercept and Treatment System reflects the Army's goal of further reducing the potential risks toward the 10^{-6} level. Using conservative assumptions, including several exposure pathways that do not currently exist, the maximum cumulative cancer risk in the Offpost OU was estimated to be 3 in 10,000, which is within the acceptable risk range established by EPA.

Although the maximum offpost cumulative carcinogenic risk is below the acceptable risk level, remediation of groundwater is preferable to no action for the following reasons:

- Groundwater concentrations exceed National Primary Drinking Water Standards maximum contaminant levels (MCLs) and CBSGs in some areas of the Offpost OU.
- Groundwater is the greatest contributor to cancer risk and contributes a maximum risk of 2 in 10,000 (or approximately 75 percent) to the cumulative risk in zones 2, 3, and 4.
- Evaluation of potential noncarcinogenic health effects indicate that HIs calculated for groundwater contaminant concentrations in zones 2, 3, and 4 are slightly greater than 1.0.

Soil, surface water, sediment, and air contribute maximum cancer risks less than 1 in 10,000 in zones 1 through 6. Soil, surface water, sediment, and air do not require remediation because of the low risks contributed by these media to the total risk. Remedial alternatives were developed and evaluated to address contaminated groundwater in the Offpost OU North and Northwest Plume Groups. Additionally, as part of the Conceptual Remedy Agreement, the Army and Shell Oil Company have agreed to till and revegetate approximately 160 acres located in the southeast portion of Section 14 and southwest portion of Section 13.

Remedial alternatives for groundwater were developed by (1) establishing groundwater containment system remediation goals , (2) identifying the areas of groundwater exceedances of containment system remediation goals , and (3) assembling combinations of remedial process options into remedial alternatives.

Containment system remediation goals (Table 7.1., 7.2, and 7.3 were established on the basis of chemical-specific applicable or relevant and appropriate requirements (ARARs), health-based criteria (HBC), exposure factors, and the statutory requirements stated in Section 121 of CERCLA. ARARs were used as groundwater containment system remediation goals for contaminants with promulgated standards, and HBC based on a risk of 1×10^{-6} calculated using RME assumptions were used for carcinogens without ARARs. A risk level of 1×10^{-6} was selected to correspond to the point of departure as defined in the NCP. The promulgated standards adopted as containment system remediation goals for Offpost OU groundwater include MCLs and CBSGs. In addition, containment system remediation goals for several contaminants with promulgated standards were adjusted

downward to reduce risk corresponding to the containment system remediation goals. For some analytes, the certified reporting limit (CRL) or the practical quantitation limit (PQL) are higher than the containment system remediation goal. The CRL and PQL represent the lower practical limit for quantitation.

Attainment of the groundwater containment system remediation goals developed for the site will reduce the estimated total hypothetical cancer risks to less than 1×10^{-4} toward the 1×10^{-6} level. Because the total cancer risk assumes that all chemicals are present in groundwater at all locations, and since groundwater contamination is variable throughout the OU, the estimated risk reduction may be greater. Attainment of the groundwater containment system remediation goals developed for the site will also reduce HIs discussed in Section 6.1.4.2 to below 1.0 for all target organ groups and receptors. Again, variability in contaminants present in groundwater may increase the estimated risk reduction from that estimated by extrapolating directly from the risk assessment.

Groundwater requiring remediation in the Offpost Study Area was identified by comparing groundwater containment system remediation goals to the areal extent of groundwater contamination. Groundwater containment system remediation goals are exceeded for the carcinogens arsenic, chloroform, DBCP, tetrachloroethylene, trichloroethylene, and dieldrin. Groundwater containment system remediation goals are also exceeded for the noncarcinogens chlorobenzene, dicyclopentadiene, and DIMP. The area of groundwater exceeding containment system remediation goals (and thus the Offpost OU) encompasses approximately 590 acres of the Offpost Study Area.

Groundwater alternatives were developed and evaluated using two groundwater models. The models simulated groundwater flow and contaminant transport for the North and Northwest Plume Groups. Groundwater modeling was used for the following purposes: developing conceptual designs for sizing and locating groundwater extraction, recharge, and treatment systems; estimating future contaminant transport; evaluating the relative merits of remediation alternatives; and estimating the

time required to clean up the contaminated groundwater. Because of the approximate nature and inherent uncertainties of the models, none of the model results should be interpreted as an accurate prediction of future conditions. The predicted remediation time frames are estimates. Accordingly, estimated remediation time frames were only used to assess the relative effectiveness of the groundwater alternatives.

Remedial alternatives were initially screened on the basis of effectiveness, implementability, cost, and attainment of ARARs. The alternatives passing the initial screening were then evaluated on the basis of nine criteria required by the NCP. In addition to remedial alternatives, the NCP requires that a No Action alternative be considered at every site. The No Action alternative serves primarily as a point of comparison for other alternatives.

A total of six alternatives for the North Plume Group and four remedial alternatives for the Northwest Plume Group were developed for analysis. Following the initial screening analysis in the FS, four remedial alternatives for the North Plume Group (N-1, N-2, N-4, and N-5) and two remedial alternatives for the Northwest Plume Group (NW-1 and NW-2) remained for evaluation during the detailed analysis of alternatives. These alternatives are described below with the original alternative numbering sequence from the FS report.

7.1 Common Elements of Alternatives

All of the alternatives developed included the following elements:

- Ground water and surface-water monitoring: Samples will be collected periodically from groundwater monitoring wells and surface-water locations throughout the Offpost Study Area and analyzed to assess changes in ground water and surface-water quality during and after remediation.
- Site review: In accordance with CERCLA, a site review will be conducted at least every five years until groundwater containment system remediation goals are achieved to assure that human health and the environment are protected during and after remediation. The site review will use monitoring program data to assess whether additional remedial action would be warranted.

Except for the No Action alternative, each alternative also includes the following activities:

- Exposure control/provision of alternate water supply as described below:

  As of the date of the Onpost ROD, and based on a .392 parts per billion (ppb) detection limit, the U.S. Army will use the last available quarterly monitoring results to determine the DIMP plume footprint.

  As part of the Onpost ROD, the U.S. Army and Shell Oil Company will pay for the extension of, and hook-up to, the current distribution system for all existing well owners within the DIMP plume footprint referenced above.

  Existing domestic well owners outside of the DIMP plume footprint as of the date of the On-post ROD where it is later determined that levels of DIMP are eight ppb or greater (or other relevant CBSG at the time) will be hooked up at the U.S. Army and Shell Oil Company's expense to the SACWSD distribution system or provided a deep well or other permanent solution.

  For new domestic wells with levels of eight ppb or greater (or other relevant CBSG at the time), the Offpost ROD institutional controls will provide that the U.S. Army and Shell Oil Company will pay for hook-up to the distribution system or provided a deep well or other permanent solution.

  Any user of a domestic well within the Offpost Operable Unit that contains groundwater contaminants derived from RMA at concentrations that exceed the greater of the remediation goals in Tables 7.1 through 7.3 or the ARARs in Table 10.1 will be provided an alternative water supply. Bottled water will be provided for cooking and drinking until a permanent alternative water supply is provided. Permanent alternative water supplies could include

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- Closure of poorly constructed wells within the Offpost Study Area - Wells that could be acting as migration pathways for contaminants in the Arapahoe Aquifer will be closed using approved methods. The pertinent criteria are presented in Appendix C - Well Closure Criteria.

7.2 Identification of Groundwater Alternatives: North Plume Group

Alternatives developed for remediation of groundwater in the North Plume Group are described below. Table 7.4 presents the alternatives corresponding to the North Plume Group and identifies process options, numbers of wells and trenches, flow rates, estimated remediation time frames, treatment facility location, and process residuals generated.

7.2.1 - Alternative N-1: No Action

Under Alternative N-1, the operation of the NBCS would be discontinued. Alternative N-1 would therefore not provide for active remediation of affected groundwater within the North Plume Group. Ceasing operation of the NBCS would likely cause an increase in contaminant concentrations within the North Plume Group. Natural fate processes, including degradation and attenuation, would be the only mechanisms that would reduce contaminant concentrations in groundwater within the North Plume Group. The major components of Alternative N-1 include the following:

- Long-term groundwater and surface-water monitoring
- Site reviews

A long-term ground water and surface-water monitoring program would be implemented. The purpose of the monitoring program is to assess changing UFS and CFS aquifer and surface-water conditions during and after remedial action. As part of Alternative N-1, a site review would be conducted at least every five years until containment system remediation goals are achieved.

The total present worth cost estimate for Alternative N-1 ranges from $4,061,000 to $6,102,000. This includes long-term operation and maintenance costs for performing site reviews, groundwater and surface-water monitoring, and regulatory oversite activities.

7.2.2 Alternative N-2: Continued Operation of the North Boundary Containment System With Improvements as Necessary

Alternative N-2 would provide for active remediation of affected groundwater approaching the north boundary of RMA through continued remediation of groundwater at the NBCS. The major components of Alternative N-2 are as follows:

- Continued operation of the NBCS
- Improvements to the NBCS as necessary
- Long-term groundwater and surface-water monitoring
- Site reviews
- Exposure control/provision of alternate water supply as described in Section 7.1
- Well closure in conformance with criteria listed in Appendix C, pages C-1 and C-2
- Institutional controls as described in Appendix B

Under Alternative N-2, the NBCS would continue to contain, extract, treat, and recharge approximately 125 million gallons of groundwater per year. Improvements would be made to the NBCS if it was determined that the system was allowing groundwater containing COCs at concentrations exceeding off post groundwater containment system remediation goals to migrate from RMA to the North Plume Group.

As part of Alternative N-2, an alternative water supply would be provided to any user of a domestic well in accordance with the provisions described in Section 7.1. The long-term groundwater and surface-water monitoring and site review remedial components under Alternative N-2 would be identical to those proposed under Alternative N-1.

The total present worth cost estimate for Alternative N-2 ranges from $30,600,000 to $32,500,000. This incudes long-term operation and maintenance costs for the NBCS and the cost of long-term ground water monitoring and site review components included under Alternative N-1.

7.2.3 Alternative N-4: Offpost Groundwater Intercept and Treatment System

Under Alternative N-4, the NBCS would continue to operate, and the Offpost Groundwater Intercept and Treatment System would be constructed and operated to contain, remove, treat, and recharge groundwater exceeding containment system remediation goals in the First Creek and northern paleochannels downgradient of the NBCS. Detailed information concerning the Offpost Groundwater Intercept and Treatment System is presented in the Final Implementation Document for the Groundwater Intercept and Treatment System North of Rocky Mountain Arsenal (HLA, 1991). The Offpost Groundwater Intercept and Treatment System has been in operation since early 1993. The major components of Alternative N-4 are as follows:

- Removal of contaminated UFS groundwater north of the RMA boundary in the First Creek and northern paleochannels using Offpost Groundwater Intercept and Treatment System groundwater extraction wells
- Treatment of organic contaminants in extracted groundwater using carbon adsorption
- Recharge of treated groundwater to the UFS using Offpost Groundwater Intercept and Treatment System recharge wells and trenches
- Continued operation of the NBCS
- Improvements to the NBCS and Offpost Groundwater Intercept and Treatment System as necessary
- Long-term groundwater and surface-water monitoring
- Site reviews
- Exposure control/provision of alternate water supply as described in Section 7.1
- Well closure in conformance with criteria listed in Appendix C, pages C-1 and C-2
- Institutional controls as described in Appendix B

Alternative N-4 would remediate UFS groundwater in the First Creek and northern paleochannels that is contaminated with organic COCs at concentrations exceeding groundwater containment system remediation goals.

Extraction wells would be used in the Offpost Groundwater Intercept and Treatment System to remove contaminated groundwater. Extracted groundwater would be conveyed to the treatment facility via double-contained polyvinyl chloride (PVC) pipelines.

Based on the results of the groundwater modeling, the configuration of five extraction wells and six recharge trenches shown in Figure 7.1 would capture and remove contaminants axially in the First Creek paleochannel. The recharge trenches would be placed both downgradient of the extraction wells and along the outer boundaries of the First Creek paleochannel. In this manner, the recharge trenches would provide both lateral hydraulic containment of the First Creek paleochannel and water flushing for enhancing the removal of contaminants. Capture would be attained using a transverse system of 12 extraction and 24 recharge wells directly downgradient of the extraction wells in the northern paleochannel system. The Offpost Groundwater Intercept and Treatment System would contain, extract, treat, and recharge approximately 480 gallons per minute (gpm). Construction of this system began in November 1991 and was completed in June 1993.

Extracted groundwater from both the First Creek and northern paleochannels would be conveyed by pipeline to a central carbon adsorption treatment facility on land in the Offpost Study Area that was previously purchased by Shell. Activated carbon adsorption is a well-developed technology that is widely used in removing organic contaminants from liquid hazardous waste streams and offgas airstreams. The waste stream comes in contact with granular activated carbon (GAC) by flowing through one or more packed-bed reactors. Organic chemicals and, to some degree, inorganic chemicals, are adsorbed onto the internal pores of the carbon granules by surface-attractive phenomena. Activated carbon removes many nondegradable organic compounds and is most effective for nonpolar, slightly soluble compounds.

Carbon adsorption is readily implementable. Carbon adsorption is a demonstrated, proven technology documented to be effective at the NWBCS, NBCS, and ICS. Activated carbon treatment would

achieve groundwater containment system remediation goals for organic contaminants before discharge via the recharge systems.

An intensive short-term monitoring component would be included in Alternative N-4 as part of the long-term monitoring program. The intensive short-term program would consist of monitoring approximately 60 wells in a network that would be finalized through implementation of the alternative. Two years of data would be collected during the period commencing with Offpost Groundwater Intercept and Treatment System operations start-up. Such a program is necessary to evaluate the performance of the NBCS and the Offpost Groundwater Intercept and Treatment System and would provide an increased understanding of contaminant transport, an estimated time to achieve groundwater containment system remediation goals, and to determine whether improvements to the Offpost Groundwater Intercept and Treatment System are warranted.

The total present worth cost estimate for Alternative N-4 ranges from $56,500,000 to $63,100,000. This includes the capital and long-term operation and maintenance cost for construction, operation, and performance monitoring of the Offpost Groundwater Intercept and Treatment System. This cost estimate also includes the continued operation of the NBCS, long-term groundwater monitoring, site review, and exposure control components of Alternative N-2.

7.2.4 Alternative N-5: Expansion of the Offpost Groundwater Intercept and Treatment System

Similar to Alternative N-4, this alternative would remediate the First Creek paleochannel and northern paleochannel groundwater downgradient of the NBCS. Based on the results of the groundwater modeling, the configuration of extraction wells and recharge systems proposed under Alternative N-5 would place additional extraction wells in locations where the limiting hydrogeologic and contaminant characteristics are controlling remediation time frames. Two additional extraction wells and four recharge trenches would be installed in the area of relatively slower groundwater velocity and high dieldrin concentrations in the First Creek paleochannel. One additional extraction

well and two recharge trenches would be installed in an area of low hydraulic conductivity in the northern paleochannel. The major components of Alternative N-5 are as follows:

- Removal of contaminated UFS groundwater north of the RMA boundary in the First Creek and northern paleochannels, using Offpost Groundwater Intercept and Treatment System groundwater extraction wells
- Expansion of the Offpost Groundwater Intercept and Treatment System extraction and recharge systems
- Treatment of extracted groundwater using carbon adsorption
- Recharge of treated groundwater to the UFS, using recharge wells and trenches
- Continued operation of the NBCS
- Improvements to the NBCS as necessary
- Long-term groundwater and surface-water monitoring
- Site reviews
- Exposure control/provision of alternate water supply as described in Section 7.1
- Well closure in conformance with criteria listed in Appendix C, pages C-1 and C-2
- Institutional controls as described in Appendix B

The expansion of the Offpost Groundwater Intercept and Treatment System is shown in Figure 7.2. The three additional extraction wells would each pump 30 gpm (90 gpm additional), and the additional trenches would recharge the same volume. Thus, Alternative N-5 would extract and treat a total of 570 gpm compared to 480 gpm for Alternative N-4. Other remedial components under Alternative N-5 would be identical to those proposed under Alternative N-4.

The total present worth cost estimate for Alternative N-5 ranges from $56,200,000 to $63,000,000. This includes the capital and operation and maintenance costs of the expansion systems to the Offpost Groundwater Intercept and Treatment System and the cost components of Alternative N-4

7.3 Identification of Groundwater Alternatives: Northwest Plume Group

The following subsections identify the alternatives developed for the Northwest Plume Group. Table 7.4 presents the alternatives corresponding to the Northwest Plume Group and identifies process options, numbers of wells and trenches, flow rate, estimated remediation time frames, treatment facility location, and process residuals generated.

7.3.1 Alternative N-1: No Action

Under Alternative NW-1, the operation of the NWBCS would be discontinued. Alternative NW-1 would not provide for active remediation of affected groundwater within the Northwest Plume Group. Ceasing operation of the NWBCS would likely cause an increase in contaminant concentrations within the Northwest Plume Group. Natural fate processes, including degradation and attenuation, would be the only mechanisms that would reduce contaminant concentrations in groundwater within the Northwest Plume Group. The major components of Alternative NW-1 are as follows:

- Long-term groundwater monitoring
- Site reviews

A long-term groundwater monitoring program would be implemented. The purpose of the monitoring program would be to assess changing UFS and CFS aquifer conditions during and after remedial action. As part of Alternative NW-1, a site review would be conducted at least every five years until containment system remediation goals are achieved.

The total present worth cost estimate for Alternative NW-1 ranges from $608,000 to $1,260,000. This includes long-term operation and maintenance costs for performing site reviews, groundwater monitoring, and regulatory oversite activities.

7.3.2 Alternative NW-2: Continued Operation of the Northwest Boundary Containment System With Improvements as Necessary

Alternative NW-2 would provide for active remediation of affected groundwater approaching the northwest boundary of RMA through continued remediation of groundwater at the NWBCS. The major components of Alternative NW-2 are as follows:

- Continued operation of the NWBCS
- Improvements to the NWBCS as necessary
- Long-term groundwater monitoring
- Site reviews
- Exposure control/provision of alternate water supply as described in Section 7.1
- Well closure in conformance with criteria listed in Appendix C, pages C-1 and C-2
- Institutional controls as described in Appendix B

Under Alternative NW-2, the NWBCS would continue to contain, extract, treat, and recharge approximately 450 million gallons of groundwater per year. Improvements would be made to the NWBCS if it was determined that the system was allowing groundwater containing COCs at concentrations exceeding offpost groundwater containment system remediation goals to migrate from RMA to the Northwest Plume Group.

As part of Alternative NW-2, an alternative water supply would be provided to any user of a domestic well that contains groundwater contaminants at concentrations exceeding containment system remediation goals . Other remedial components under Alternative NW-2 would be identical to those proposed under Alternative NW-1.

The total present worth cost estimate for Alternative NW-2 ranges from $12,400,000 to $13,100,000. This includes long-term operation and maintenance costs for the NWBCS and the long-term groundwater monitoring, site reviews, and exposure control components of Alternative NW-1.